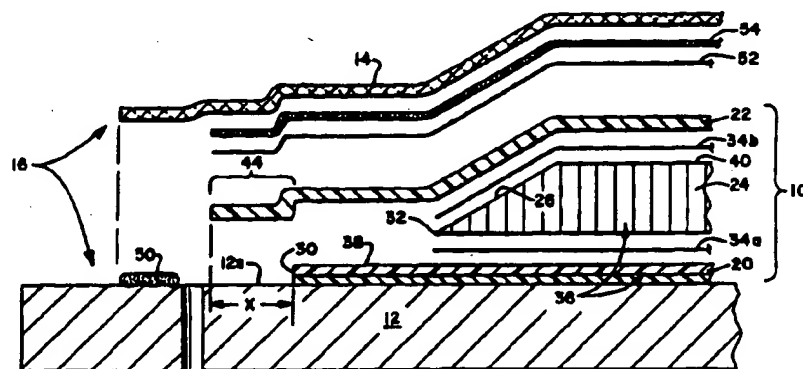




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B29D 24/00, B29C 70/54, 70/44	A1	(11) International Publication Number: WO 96/22878 (43) International Publication Date: 1 August 1996 (01.08.96)
(21) International Application Number: PCT/US95/01099 (22) International Filing Date: 27 January 1995 (27.01.95) (71) Applicant (for all designated States except US): SIKORSKY AIRCRAFT CORPORATION [US/US]; Legal-Intellectual Property, Mailstop Z209A, P.O. Box 9729, 6900 Main Street, Stratford, CT 06497-9129 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): FORSTER, William, V. [US/US]; 11a Lilac Drive, Seymour, CT 06483 (US). NOWAK, Kenneth, M. [US/US]; 63 Herrmann Lane, Easton, CT 06612 (US). OSIECKI, Larry, J. [US/US]; 197 Moose Hill Road, Oxford, CT 06478 (US). (74) Agent: COLLINS, Brian, A.; Sikorsky Aircraft Corporation, Legal-Intellectual Property, Mailstop Z209A, P.O. Box 9729 - 6900 Main Street, Stratford, CT 06497-9129 (US).		(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, ARIPO patent (KE, MW, SD, SZ), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: METHOD FOR MAKING HONEYCOMB CORE COMPOSITE ARTICLES**(57) Abstract**

A method for making a honeycomb core composite article includes forming a honeycomb core (24) and a precured composite skin (20) having a core edge (32) and a restraint edge (30), respectively. The precured composite skin (20) is placed in combination with a rigid mold member having a mold surface (12s) and the honeycomb core (24) is mated with the precured composite skin (20) to form a mated subassembly (36). An uncured composite skin (22) is laid over the mated subassembly (36) such that a peripheral portion (44) of the uncured composite skin (22) extends beyond the restraint edge (30) by a distance X and such that the peripheral portion (44) is in superposed abutting engagement with the mold surface (12s). The honeycomb core (24), the precured composite skin (20) and the uncured composite skin (22) define a composite lay-up (10) over which a vacuum bag (14) is disposed. The resultant mold cavity (60) is evacuated to urge the vacuum bag (14) against the uncured composite skin (22) thereby effecting engagement of the peripheral portion (44) with the restraint edge (30) and the mold surface (12s). The composite lay-up (10) is then cured to form the completed honeycomb core composite article. The method produces a honeycomb core composite article wherein the honeycomb core (24) thereof is accurately located and substantially distortion-free.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

Description

Method For Making Honeycomb Core Composite Articles

5 **Technical Field**

The present invention relates to manufacturing honeycomb core composite articles, and more particularly, to an improved method of manufacturing such composite articles wherein the honeycomb core thereof is accurately located and substantially distortion-free.

10 **Background Of The Invention**

Composite articles incorporating honeycomb cores are commonly utilized for fabricating aerospace structures due to their advantageous strength to weight ratio. Honeycomb core (HC) composite articles are typically comprised of upper and lower
15 composite skins, i.e., fiber reinforced resin matrix laminates, that are separated and stabilized by the honeycomb core. Due to the high bending stiffness and compressive strength properties of HC composite articles, i.e., the honeycomb core functions as a shear web and spaces the composite skins from the bending neutral axis, HC composite
20 articles have particular utility in aerospace applications such as aircraft fuselage panels and door structures. The high strength and low weight of such construction results in lower overall aircraft system weight.

HC composite articles may be fabricated utilizing various composite forming methods. The most commonly employed technique
25 involves the use of a vacuum bag molding assembly wherein an impervious membrane or "vacuum bag" is employed for consolidating the composite skins and ensuring proper adhesion thereof to the centrally disposed honeycomb core. More specifically, the lower composite skin, honeycomb core, and upper composite skin are
30 sequentially laid in a rigid mold member so that the honeycomb core is overlaid by the upper and lower composite skins. The upper and lower composite skins are formed from uncured "prepreg" or "B-stage" laminates comprised of a fiber reinforcement such as graphite, aramide or fiberglass fibers disposed in a binding matrix such as epoxy, phenolic
35 or other similar organic resinous material. Film adhesive, which is applied to the honeycomb core prior to the lay-up, forms the bonds

between the upper and lower composite laminates and the honeycomb core. The vacuum bag is disposed over the rigid mold member and sealed thereto so as to form a mold cavity which is occupied by the uncured composite lay-up. The mold cavity is then evacuated and
5 additional pressure and temperature are applied via an autoclave oven to cure the lay-up. The combination of vacuum and external pressure functions to consolidate the composite skins, remove air and volatiles from the resin binder, and apply the necessary compaction pressure to ensure full and uniform adhesion of the lay-up.

10 Difficulties commonly encountered during the fabrication of HC composite articles relate to shifting and/or distortion of the honeycomb core under compaction pressure. While the honeycomb core is relatively stable in the direction of the individual cells, i.e., the cells provide significant buckling stability, it will be appreciated that pressure
15 applied transversely of the cells may cause distortion and/or shifting, e.g., accordioning, of the honeycomb core due to the inadequate strength thereof in a lateral direction. This is more clearly understood by reference to Fig. 1a wherein a lay-up of upper and lower composite skins 100, 102, and a honeycomb core 104 is disposed in a vacuum bag
20 molding assembly 108. The vacuum bag 110 is shown applying a lateral component of pressure P along the ramped edges of the honeycomb core, which lateral pressure component causes the local collapse and distortion of the honeycomb core edges. Fig. 1b shows a top view of the cured HC composite article wherein the distortion, indicated by dashed lines 112, is exaggerated for illustrative purposes.

25 Attempts to overcome problems of distortion and shifting have included stabilization techniques wherein the edges of the honeycomb core, i.e., several rows of honeycomb cells about the entire periphery, are stabilized by the application of film adhesive or filled with a low
30 density syntactic foam. Once cured, the film adhesive and/or the foam-filled cells serve to retard the accordioning of the honeycomb core. U.S. Patents 4,680,216 and 5,354,195 discuss honeycomb core stabilization techniques and various materials useful therefor. While these techniques have been marginally successful in limiting distortion
35 of the honeycomb core (on the order of about .64 cm to .95 cm (.25 in to .375 in), such materials are substantially parasitic and are not practical for applications wherein minimization of overall aircraft weight

is a critical design criterion. Furthermore, these stabilization options are not acceptable for applications wherein accurate and distortion-free core location is highly critical. For example, applications requiring the use of radar absorbent (i.e., carbon-loaded) honeycomb core to defeat enemy radar require far more exacting manufacturing tolerances than those which can be produced by prior art stabilization techniques. If shifting of the radar absorbent honeycomb core should occur during the manufacturing process, radar coverage on the aircraft could be compromised.

Other attempts to yield a distortion-free core have included the use of restraint devices formed or assembled about the periphery of the molding assembly. Fig. 2a depicts a vacuum bag molding assembly wherein rows of vertically protruding pins 120 are affixed to a rigid mold member 122 and disposed in adjacent relation to the HC composite article 124 to be formed. As the upper composite skin 126 is laid over the honeycomb core 128, the pins 120 are caused to engage a peripheral portion 130 of the upper composite skin 126, i.e., pierce the composite fabric, to prevent lateral displacement thereof during the molding/compaction process. A bridging effect is thereby created in the upper composite skin 126, i.e., between the uppermost corner 132 of the honeycomb core 128 and the mating surface 134 of the lower composite skin 136, to react lateral compaction pressure and, consequently, prevent distortion of the honeycomb core 128. While this technique is suitable for high tolerance applications, e.g., LO applications, the protruding pins 120 are a source of high maintenance, i.e., requiring periodic cleaning and repair, pose a hazard to the operator, and create difficulties when sealing the vacuum bag 138 to the rigid mold member 122. Regarding the latter, the vacuum bag 138 must be sealed outboard of the protruding pins 120, thus requiring the additional step of disposing a protective elastomer strip 139 over the protruding pins 120 to prevent damage to the vacuum bag 138.

A similar approach is shown in Fig. 2b wherein a perforated or apertured metal strip 140 is substituted for the protruding pins 120. The peripheral portion 130 of the upper composite skin 126 is laid over the apertured metal strip 140 such that under compacting pressure the apertures 142 thereof capture or grip the peripheral portion 130 to prevent lateral displacement of the upper composite skin 126. This

approach yields similar results to the above-described pinned configuration, however, laborious cleaning is required to remove excess resin from the apertures 142 prior to initiating the next cure cycle.

5 A need therefore exists to provide an improved method of manufacturing HC composite articles which provides accurate and distortion-free core location and minimizes repair and/or maintenance of the molding assembly.

Disclosure Of Invention

10 It is an object of the present invention to provide a method for manufacturing HC composite articles wherein the honeycomb core thereof is accurately located and substantially distortion-free.

It is another object of the present invention to provide a method for manufacturing HC composite articles wherein modifications to and maintenance of the molding assembly are minimized.

15 A HC composite article is fabricated by the steps of: forming a honeycomb core having a core edge, forming a precured uncured composite skin having a restraint edge, placing the precured composite skin in combination with a rigid mold member defining a mold surface, mating the honeycomb core to the precured uncured composite skin to
20 form a mated subassembly wherein the restraint edge extends beyond the core edge, laying-up an uncured composite skin over the mated subassembly so that a peripheral portion of the uncured composite skin extends beyond the restraint edge by a distance X, and so that the peripheral portion is in superposed abutting engagement with the mold
25 surface and wherein the honeycomb core, precured composite skin and uncured second composite skin define a composite lay-up, disposing a vacuum bag over the composite lay-up to form a mold cavity between the mold surface and the vacuum bag, evacuating the mold cavity for urging the vacuum bag against the uncured composite skin and for
30 compacting the same against the mated subassembly, the vacuum bag effecting engagement of the peripheral portion with the restraint edge and the mold surface for preventing lateral displacement of the uncured composite skin, and curing the uncured composite skin to form the HC composite article.

35 The foregoing and other objects, features and advantages of the present invention will become more apparent in light of the following

detailed description of exemplary embodiments thereof, as illustrated in the accompanying drawings.

Brief Description Of The Drawings

5 A more complete understanding of the present invention and the attendant features and advantages thereof may be had by reference to the following detailed description of the invention when considered in conjunction with the following drawings wherein:

10 Figs. 1a and 1b depict a honeycomb core (HC) composite article being formed in a vacuum bag molding assembly and the resultant distortion of the honeycomb core under molding assembly pressure;

Figs. 2a and 2b depict prior art molding apparatus for preventing distortion of a vacuum-formed HC composite article;

15 Fig. 3 depicts an exploded partial cross-sectional view of a HC composite lay-up employing the teachings of the present invention;

Fig. 4 depicts the HC composite article manufactured by the method of the present invention, and more particularly, the consolidation of the lay-up by a vacuum bag molding assembly.

Best Mode For carrying Out The Invention

20 Referring now to the drawings wherein like reference characters identify corresponding or similar elements throughout the several views, Fig. 3 depicts an exploded partial cross-sectional view of a honeycomb core (HC) composite lay-up 10 disposed between a rigid mold member 12 and a vacuum bag 14 which, in combination, form a vacuum bag mold assembly 16. The composite lay-up 10 includes
25 precured and uncured composite skins 20, 22, and a honeycomb core 24 disposed therebetween.

30 The honeycomb core 24 may be any of the conventionally used open cellular honeycombs such as aluminum, phenolic or NOMEX® (NOMEX is a registered trademark of Hexcel Corp., Chatsworth, CA for an aramid fiber or fabric). For applications wherein weight is a critical design criterion, a lightweight honeycomb core having a density of about 28.84 Kg/m^3 (1.8 lbs/ft^3) is preferred. Generally, honeycomb core is purchased in bulk and machined to the desired shape and size using Numerically Controlled (NC) machining apparatus. While the
35 honeycomb core 24 is shown to have a ramped surface 26 to gradually transfer shear loads to the precured and uncured composite

skins 20, 22, it will be understood that the teachings of the present invention are equally applicable to honeycomb cores having right-angled surfaces.

5 The precured composite skin 20 is comprised of fiber reinforced resin matrix composite laminates having a fiber reinforcement such as graphite, aramide or fiberglass fibers disposed in a binding matrix such as epoxy, phenolic or other similar organic resinous material. Preferably, two composite laminates having a total thickness of at least about .038 cm (.015 in) are laid-up in a mold assembly and cured to
10 form a cured composite panel. Any conventional fabrication method, such as vacuum forming, resin transfer molding, or matched metal molding may be used to form and cure the composite panel. The preferred method, however, utilizes a vacuum bag mold assembly wherein the same rigid mold member 12 employed for forming the HC composite lay-up is used for forming the precured composite skin 20.
15 Once cured, at least one end of the cured composite panel is trimmed, thus forming the precured composite skin 20. The trimming operation also produces a restraint edge 30 having a right-angled configuration 30'. The utility of this construction will become evident when
20 discussing the subsequent processing steps.

The precured composite skin 20 is then returned to the rigid mold member 12 and the honeycomb core 24 is mated therewith to form a mated subassembly 36 (see Fig. 4). Furthermore, the honeycomb core 24 is disposed in superposed relation with the precured composite skin 20 so that restraint edge 30 extends beyond the edge 32 of the
25 honeycomb core 24. That portion of the precured composite skin 20 extending beyond the core edge 32 also defines a mating surface 38. The mating step additionally includes the application a bonding adhesive 34a to one or both of the mating surfaces, i.e., to either the
30 honeycomb core 24 or the precured composite skin 20, for bonding the core to the precured composite skin 20. In the preferred embodiment, the bonding adhesive 34a is co-cured with the completed composite lay-up 10, i.e., concurrent with the curing step (cure cycle) described hereinbelow. However, it is also contemplated that the bonding
35 operation may be performed prior to subsequent processing steps, e.g., as a independent operation requiring a unique cure cycle. The

preferred bonding adhesive 34a is a film adhesive such as EA 9690 manufactured by Hysol Corp located in Pittsburgh, CA.

5 The uncured composite skin 22 is comprised of one or more laminates of uncured preimpregnated fiber reinforced composite material having a fiber reinforcement such as graphite, aramide or fiberglass fibers disposed in a binding matrix such as epoxy, phenolic or other similar organic resinous material. In the preferred embodiment, a bonding adhesive 34b, such as Hysol 9690 film adhesive, is first applied to the exposed upper surface 40 of the honeycomb core 24 in
10 preparation for the lay-up of the uncured composite skin 22. The adhesive 34b facilitates the bonding of the uncured composite skin 22 to the honeycomb core 24, however, it will be appreciated that the uncured binding matrix, i.e., resin of the uncured composite skin 22, may adequately wet the honeycomb core surface during the cure cycle
15 to effect a suitable bond, thereby eliminating the need for the bonding adhesive 34b.

The uncured composite skin 22 is laid over the mated subassembly 36 and is precompacted using convention debulking techniques to ensure intimate contact with the exposed upper
20 honeycomb core surface 40 and the mating surface 38 of the precured composite skin 20. Furthermore, the uncured composite skin 22 is appropriately sized so as to permit a peripheral portion 44 thereof to extend beyond the restraint edge 30 of the precured composite skin 20. Moreover, the peripheral portion 44 is in superposed abutting
25 engagement with the mold surface 12s of the rigid mold member 12 and extends a distance X beyond the restraint edge 30. Preferably, the peripheral portion 44 extends at least 1.9 cm (.75 in) beyond the edge 30 and, more preferably, about 2.5 cm (1 in) beyond the edge 30.

The vacuum bag 14 is disposed over the completed composite lay-up 10 and sealed to the rigid mold member 12, or to itself, utilizing a conventional sealer strip 50 such as "Prestite" (Prestite is a brand name of a semi-adhesive compliant material produced by 3M located in St. Paul, MN). Optionally, a separator or release film 52 and a breather ply 54 may be interposed between the uncured composite skin 22 and
30 the vacuum bag 14. The separator film 52 facilitates release of the vacuum bag 14 after curing the composite lay-up 10 while the breather ply 54 facilitates the removal of air and volatiles from the uncured
35

composite skin 22 during the cure cycle. Representative materials are specified in the below-described example. In the described embodiment, the use of the release film 52 and breather ply 54 are preferred, however, the composite lay-up 10 is minimally comprised of the honeycomb core 24, the precured composite skin 20, and the uncured composite skin 22.

The completed vacuum bag molding assembly 16 shown in Fig. 4 forms a sealed mold cavity 60, i.e., between the rigid mold member 12 and the vacuum bag 14, which is in fluid communication with a vacuum pump 62. The vacuum pump 62 functions to evacuate the mold cavity 60 of gaseous fluids, i.e., air and volatiles, and to create a pressure differential for urging the vacuum bag 14 against the uncured composite skin 22. Concomitantly, the peripheral portion 44 of the uncured composite skin 22 is forced into engagement with the restraint edge 30 of the precured composite skin 20 and against the mold surface 12s.

The vacuum bag molding assembly 16 is then placed in an autoclave oven (not shown) wherein the composite lay-up 10 is exposed to additional pressure and temperature for curing. For the described embodiment, the autoclave oven applies a pressure of about 3.72×10^7 - $4.46 \times 10^7 \text{ N/m}^2$ (25 - 30 lbs/in²) to the lay-up and elevates the temperature thereof to about 121 - 232°C (250 - 450° F) degrees for a period of about 120 - 180 mins.

During the vacuum forming step, i.e., evacuation of the mold cavity 60, and subsequent curing step, the peripheral portion 44 of the uncured composite skin 22 engages the restraint edge 30 of the precured composite skin 20 so as to provide a mechanical interlock therebetween. The restraint edge 30 functions to inhibit the lateral displacement of the uncured composite skin 22 and, consequently, cause a bridging effect therein in the region overlaying the ramped honeycomb surface 26. As discussed supra, the bridging effect functions to react the lateral component of pressure P applied by the vacuum bag 14. Concomitantly, the contacting interface CI between the peripheral portion 44 and the mold surface 12s, provides additional restraint toward the objective of inhibiting lateral displacement. That is, the frictional force along the contacting interface CI augments the restraint capacity of the restraint edge 30. Accordingly, by inhibiting

lateral displacement and, consequently, the catenary displacement of the uncured composite skin 22, shifting and/or distortion of the honeycomb core 24 is minimized.

5 While the completed HC composite article may be used in the configuration produced by the foregoing process steps, the cured composite lay-up may be trimmed along line T_L to net dimension to form a honeycomb core composite article having a uniform thickness peripheral flange 70. Preferably, the restraint edge 30 and the peripheral portion 44 are removed during this operation. Accordingly, 10 the trimming operation removes the abrupt contour transition produced by the restraint edge 30 which enhances the strength of peripheral flange 70 for subsequent fastening and/or bonding operations.

The restraint edge 30 and the mold surface 12s are tooling surfaces which are functionally equivalent to the prior art pinned and 15 perforated metal strip configurations, however, it will be appreciated that the formation of these tooling surfaces is far less labor intensive. The restraint edge 30 is formed in conjunction with the manufacturing process and becomes an integral part of the finished HC composite article. Furthermore, the only additional step involves the formation of 20 the precured composite skin 20. Insofar as it is advantageous to precure a composite laminate for the purposes of improving laminate quality and strength, the method of the present invention will have no adverse cost effect on the manufacturing process when such improved quality and strength are desired. For example, the precured composite skin 20 25 may be formed under a pressure of $1.11 \times 10^8 \text{ N/m}^2$ (75 lbs/in²) to improve the fiber volume content, i.e., increase the fiber to resin ratio, and, consequently, the strength of the composite laminate. Such increased fiber volume is not achievable using conventional co-cure methods, i.e., wherein both composite skins are uncured before entering 30 the autoclave oven, insofar as high compaction pressures cannot be transferred via the low density honeycomb core.

With regard to fabricating the rigid mold member 12 to include the mold surface 12s, which is slightly enlarged for superpositioning of the peripheral portion 44, it will be appreciated that fabricating such an 35 additional area surface is inconsequential in terms of time and labor.

It will also be appreciated that the hazards and periodic maintenance of the prior art tooling surfaces are entirely eliminated by

the method of the present invention. That is, the present method does not introduce hazardous tooling surfaces ,e.g., pins, or other tooling surfaces, e.g., apertures which require periodic cleaning.

5

EXAMPLE

A honeycomb core (HC) composite article was fabricated using the teachings of the invention as follows. A sheet of 1.8 lbs/ft³ NOMEX® honeycomb core was machined to a thickness dimension of 3.0 cm (1.18 in), and a length and width dimension of 60.1 cm (24 in),
10 respectively. The edges of the honeycomb core were beveled to form a 30° ramp angle about the entire periphery. The honeycomb core was then cleaned with alcohol and dried in an oven at 65.5° C (150° F) for a period of 120 minutes.

A first composite skin was formed by cutting two plies of
15 KEVLAR® fiber reinforced composite material (KEVLAR® is a registered trademark of E.I. du Pont de Nemours & Co. located in Wilmington, DE for an aromatic polyamide of high tensile strength) to a length and width dimension of 66.04 cm (26 in), respectively. The plies were sequentially laid in a rigid mold member of a vacuum bag molding
20 assembly. A Fluorinated Ethylene-Propylene (FEP) separator film and a breather ply formed from a compliant porous material such as N-10 (the FEP film and N-10 ply were obtained from Airtech International located in Carson, CA) were respectively applied to the lay-up. A vacuum bag was applied to the lay-up and sealed to the rigid mold member using
25 Prestite adhesive. The completed vacuum bag molding assembly was then placed in an autoclave oven to cure the plies. In the autoclave oven, the composite plies were step-cured for a period of 180 mins to a peak pressure and temperature of 1.11×10^8 N/m² (75 lbs/in²) and 182.2°C (360° F), respectively. The lay-up resulted in a cured
30 composite panel having a thickness dimension of .015 in. The cured composite panel was then trimmed about its periphery to form a precured composite skin having a restraint edge. The net size of the precured composite skin was approximately 63.5 cm (25 in) square.

The precured composite skin was returned to the rigid mold
35 member and a first layer of Hysol 9690 film adhesive was applied to the entire exposed surface. The prior-formed honeycomb core was then mated upon and centered over the precured composite skin so that the

restraint edge extended approximately 2.54 cm (1 in) beyond the edge of the honeycomb core. A second layer of Hysol 9689 film adhesive was then applied to the exposed upper surface of the honeycomb core.

5 An uncured composite skin comprising two plies of KEVLAR® material was laid over the mated subassembly, i.e., the honeycomb core and the precured composite skin, so that a peripheral portion of the uncured composite skin extended 2.54 cm (1 in) beyond the restraint edge of the precured composite skin. The uncured composite skin was debulked using conventional vacuum debulking apparatus for 5
10 minutes. An FEP separator film and an N-10 breather ply were sequentially laid over the uncured composite skin. A vacuum bag was then placed over the uncured composite skin and sealed to the rigid mold member, thereby forming a completed vacuum bag molding assembly. The mold cavity was evacuated so as to apply atmospheric
15 pressure (full vacuum) via the vacuum bag to the underlying composite lay-up. The peripheral portion of the uncured composite skin was thereby simultaneously forced into engagement with the restraint edge of the precured composite skin and the mold surface of the rigid mold member, respectively.

20 The vacuum bag molding assembly was then placed in an autoclave oven and step-cured as follows. The autoclave pressure was raised to 1.49×10^7 N/m² (10 lbs/in²) and autoclave temperature was elevated to 93.3° C (200°F) for a first hold phase of 60 minutes. Approximately 30 minutes into the first hold phase, the autoclave
25 pressure was gradually increased to 3.72×10^7 N/m² (25 lbs/in²). Following the first hold phase, the temperature was gradually raised to 182.2° C (360 °F) and held at a second hold phase (final cure phase) for 120 minutes.

30 The honeycomb core of the resultant composite article was found to be substantially distortion-free and accurately located relative to the composite skins.

The above described method may be used alone or in combination with various core stabilization techniques such as those described in U.S. Patents 4,680,216 and 5,354,195. Furthermore,
35 debulking operations may be performed between each of the above described lay-up steps to improve the efficacy of the resultant bonds.

Although the invention has been shown and described with respect to exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and other changes, omissions and additions may be made therein and thereto, without departing from the spirit and scope of the present invention.

5

What is claimed is:

- 1 1) A method for making a honeycomb core composite article
2 comprising the steps of:
3 forming a honeycomb core (24) having a core edge (32);
4 forming a precured composite skin (20) having a restraint
5 edge (30);
6 placing said precured composite skin (20) in combination with a
7 rigid mold member (12) having a mold surface (12s);
8 mating said honeycomb core (24) to said precured composite
9 skin (20) thereby forming a mated subassembly (36) wherein said
10 restraint edge (30) extends beyond said core edge (32);
11 laying-up an uncured composite skin (22) over said mated
12 subassembly (36) so that a peripheral portion (44) of the uncured
13 composite skin (22) extends beyond said restraint edge (30) by a
14 distance X and, furthermore, so that said peripheral portion (44) is in
15 superposed abutting engagement with said mold surface (12s), and
16 wherein said honeycomb core (24), said precured composite skin (20)
17 and said uncured composite skin (22) in combination define a
18 composite lay-up (10);
19 disposing a vacuum bag (14) over said composite lay-up (10)
20 thereby forming a mold cavity (60) between said mold surface (12s) and
21 said vacuum bag (14);
22 evacuating said mold cavity (60) to urge said vacuum bag (14)
23 against said uncured composite skin (22) for compacting the same
24 against said mated subassembly (36), said vacuum bag (14) effecting
25 engagement of said peripheral portion (44) with said restraint edge (30)
26 and said mold surface (12s) for preventing lateral displacement of said
27 uncured composite skin (22); and,
28 curing said composite lay-up (10) to form the honeycomb core
29 composite article.
- 1 2) The method according to claim 1 wherein said step of mating
2 said honeycomb core (24) to said precured composite skin (20) includes
3 the substep of applying a film adhesive (34a) between said honeycomb
4 core (24) and said precured composite skin (20).

- 1 3) The method according to claim 2 further including the step of
2 applying a bonding adhesive (34b) between said mated subassembly
3 (36) and said uncured composite skin (22).
- 1 4) The method according to claim 1 wherein said uncured
2 composite skin (22) is laid-up such that said distance X is greater than
3 about 1.9 cm (.75 in).
- 1 5) The method according to claim 1 further including the step of
2 trimming the cured honeycomb core composite article so that said
3 restraint edge (30) and said peripheral portion (44) are removed.
- 1 6) The method according to claim 1 wherein said step of forming
2 said precured composite skin (20) includes forming said precured
3 composite skin (20) so that the thickness thereof is greater than about
4 .038 cm (.015 in) and so that said restraint edge (30) defines a right
5 angled configuration (30').
- 1 7) The method according to claim 1 wherein said step of forming
2 said precured composite skin (20) includes vacuum forming a lay-up of
3 composite laminates in said rigid mold member (12), and trimming said
4 vacuum-formed lay-up to form said restraint edge (30) of said precured
5 composite skin (20).
- 1 8) The method according to claim 1 further including the step of
2 applying a release film (52) in combination with said uncured composite
3 skin (20).
- 1 9) The method according to claim 8 further including the step of
2 applying a breather ply (54) in combination with said release film (52).
- 1 10) A method for making a honeycomb core composite article
2 comprising the steps of:
3 forming a honeycomb core (24) having a core edge (32);
4 forming a precured composite skin (20) having a restraint
5 edge (30), said precured composite skin (20) being formed so that the
6 thickness thereof is greater than about .038 cm (.015 in);

7 placing said precured composite skin (20) in combination with a
8 rigid mold member (12) having a mold surface (12s);
9 mating said honeycomb core (24) to said precured composite
10 skin (20) thereby forming a mated subassembly (36) wherein said
11 restraint edge (30) extends beyond said core edge (32);
12 laying-up an uncured composite skin (22) over said mated
13 subassembly (36) so that a peripheral portion (44) of the uncured
14 composite skin (22) extends beyond said restraint edge (30) by a
15 distance greater than about 1.9 cm (.75 in) and, furthermore, so that said
16 peripheral portion (44) is in superposed abutting engagement with said
17 mold surface (12s), and wherein said honeycomb core (24), said
18 precured composite skin (20) and said uncured composite skin (22) in
19 combination define a composite lay-up (10);
20 disposing a vacuum bag (14) over said composite lay-up (10)
21 thereby forming a mold cavity (60) between said mold surface (12s) and
22 said vacuum bag (14);
23 evacuating said mold cavity (60) to urge said vacuum bag (14)
24 against said uncured composite skin (22) for compacting the same
25 against said mated subassembly (36), said vacuum bag (14) effecting
26 engagement of said peripheral portion (44) with said restraint edge (30)
27 and said mold surface (12s) for preventing lateral displacement of said
28 uncured composite skin (22);
29 curing said composite lay-up (10) to form the honeycomb core
30 composite article; and,
31 trimming said honeycomb core composite article so that said
32 restraint edge (30) and said peripheral portion (44) are removed.

1 11) The method according to claim 10 wherein said step of forming
2 said precured composite skin (20) includes the steps of vacuum forming
3 a lay-up of composite laminates in said rigid mold member (12), and
4 trimming said vacuum formed lay-up to form said restraint edge (30) of
5 said precured composite skin (20).

1 12) The method according to claim 10 further including the step of
2 applying a release film (52) in combination with said uncured composite
3 skin (20).

- 13) The method according to claim 10 further including the step of applying a breather ply (54) in combination with said release film (52).

1/4

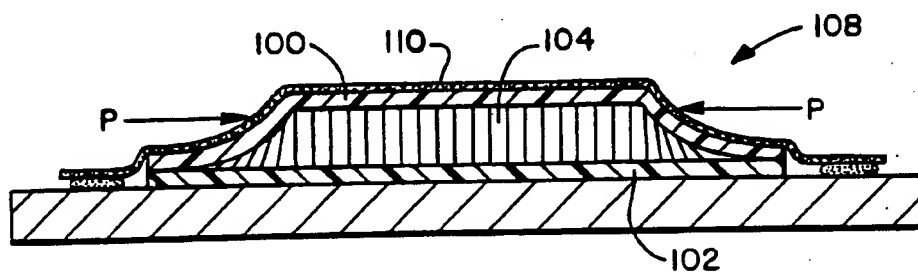


FIG. 1a

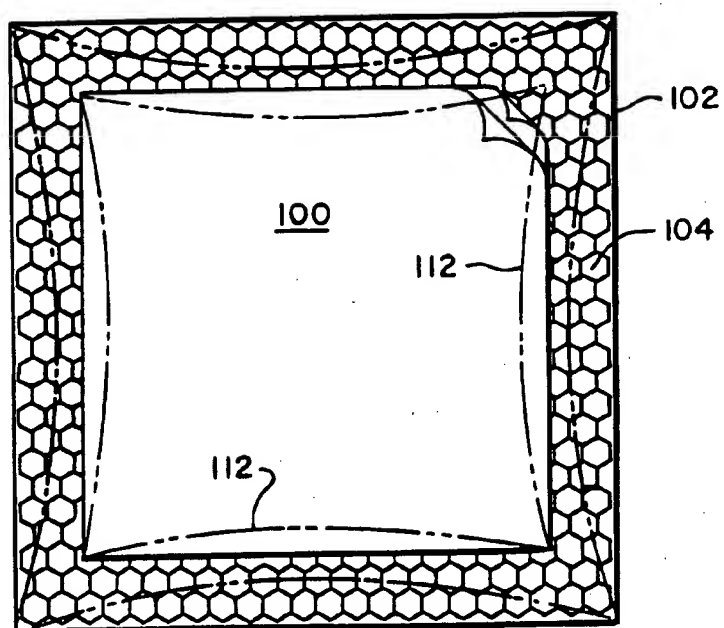


FIG. 1b

SUBSTITUTE SHEET (RULE 26)

2/4

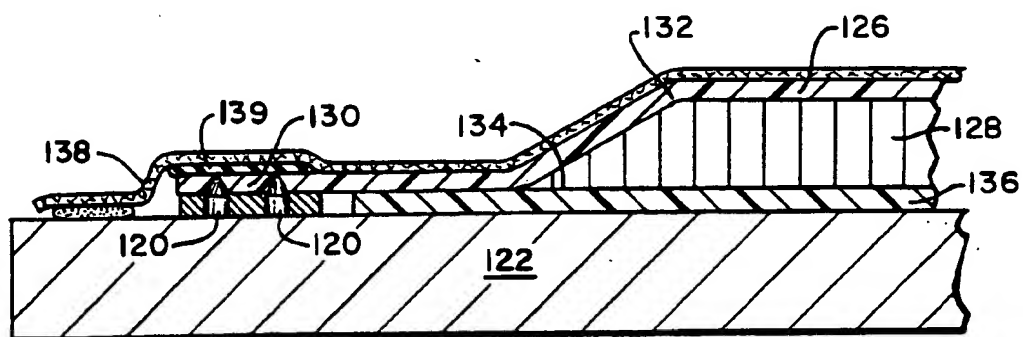


FIG. 2a
PRIOR ART

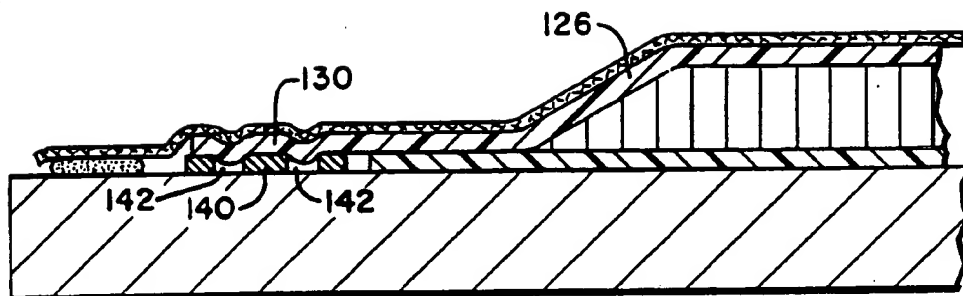


FIG. 2b
PRIOR ART

SUBSTITUTE SHEET (RULE 26)

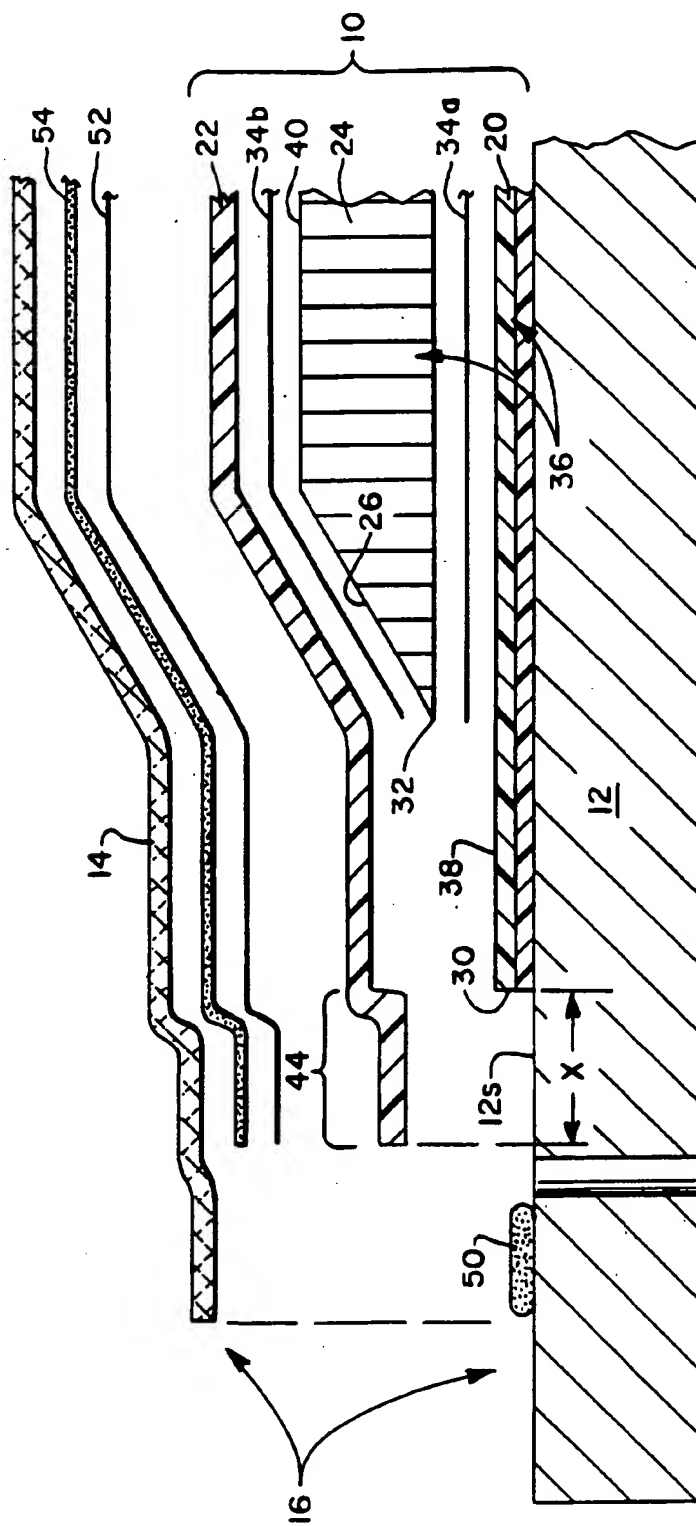


FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/01099

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B29D24/00 B29C70/54 B29C70/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B29D B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,94 14600 (UNITED TECHNOLOGIES CORP) 7 July 1994 cited in the application ---	1,10
A	US,A,4 680 216 (JACARUSO GARY J) 14 July 1987 cited in the application ---	1,10
A	US,A,4 542 056 (ANGLIN JEANNE M ET AL) 17 September 1985 ---	1,10
A	US,A,4 826 106 (ANDERSON ROBERT E) 2 May 1989 ---	1,10
A	US,A,5 242 651 (BRAYDEN THOMAS H ET AL) 7 September 1993 ---	1,10
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "B" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search

22 January 1996

Date of mailing of the international search report

5-02-96

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Roberts, P

INTERNATIONAL SEARCH REPORT

Int: nal Application No
PCT/US 95/01099

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR,A,2 383 769 (CHRYSLER FRANCE) 13 October 1978 ---	1,10
A	US,A,4 053 667 (SMITH BRUCE W) 11 October 1977 -----	1,10

1

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 95/01099

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9414600	07-07-94	US-A- 5354195 AU-B- 5870194 CA-A- 2148470 EP-A- 0675796	11-10-94 19-07-94 07-07-94 11-10-95
US-A-4680216	14-07-87	AU-B- 591163 AU-B- 6162286 CA-A- 1253424 DE-A- 3628514 FR-A- 2603520 GB-A- 2193924	30-11-89 25-02-88 02-05-89 03-03-88 11-03-88 24-02-88
US-A-4542056	17-09-85	US-A- 4599255	08-07-86
US-A-4826106	02-05-89	NONE	
US-A-5242651	07-09-93	NONE	
FR-A-2383769	13-10-78	NONE	
US-A-4053667	11-10-77	NONE	